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Oda et al.

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(54) **STEAM ENGINE**

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(52) **U.S. Cl.** **60/645**; 60/660; 60/670
(58) **Field of Search** 60/643, 645, 660, 60/670

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(57) **ABSTRACT**

A stem engine has a fluid container, a heating device and a cooling device. The fluid container has an outer pipe having an upper closed end, and an inner pipe provided in the outer pipe and having a fluid inlet port through which the inside of the inner pipe is operatively communicated with the outside of the inner pipe. The inner pipe has a pressure control device at its lower end, and a fluid injection port at its upper end for injecting the working fluid in the inner pipe into a space defined between the inner pipe and the outer pipe, when the pressure in the inner pipe is increased. The working fluid injected into the space between the inner and outer pipes is heated and vaporized by the heating device, so that volumetric expansion of the working fluid takes place to increase fluid pressure in the fluid container. The vaporized steam is then cooled and liquidized by the cooling device and thereby the volumetric contraction takes place, so that the fluid pressure is decreased. By repeating the above volumetric expansion and contraction of the working fluid, the pressure change is given to the working fluid in the fluid container.

24 Claims, 5 Drawing Sheets

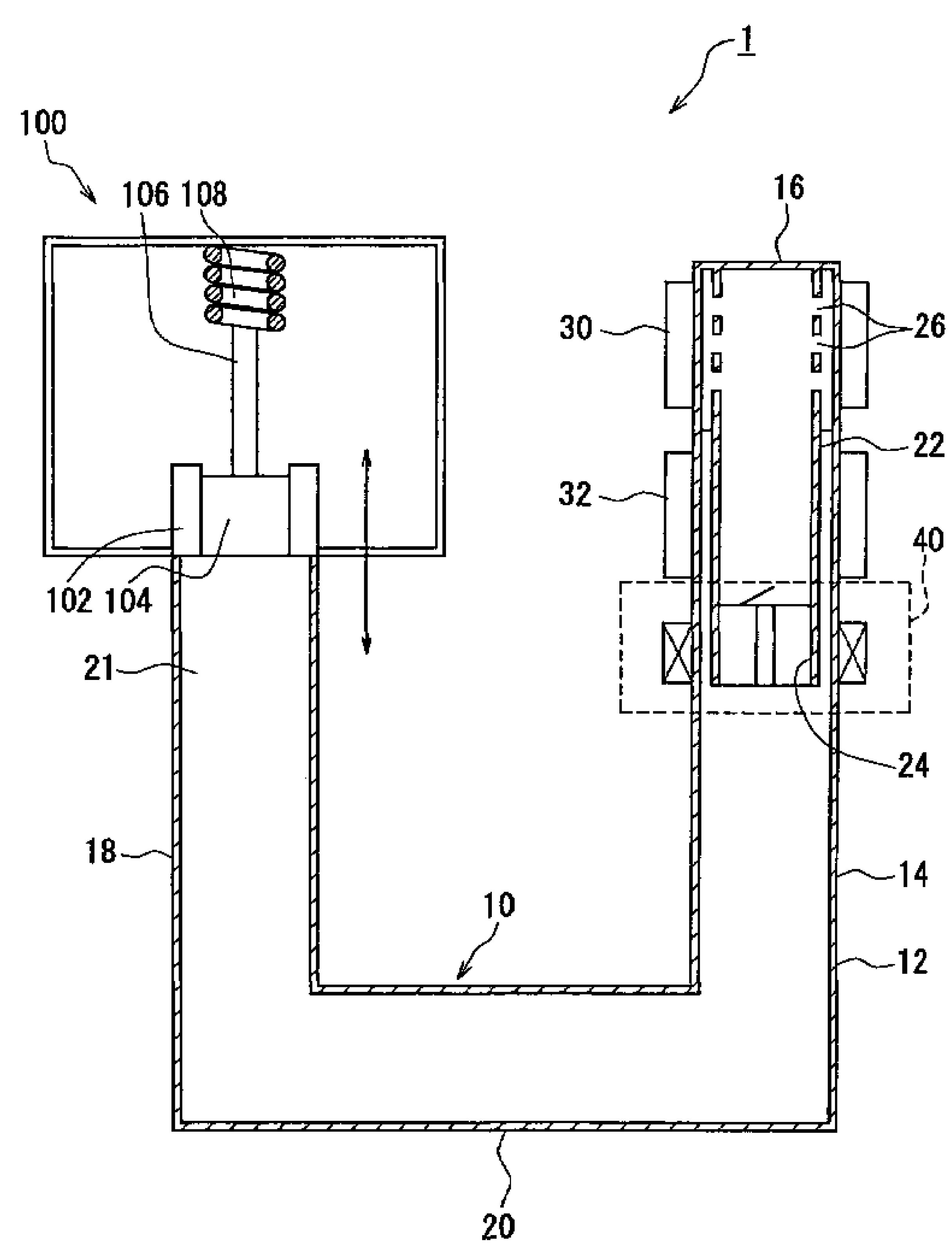


FIG. 1

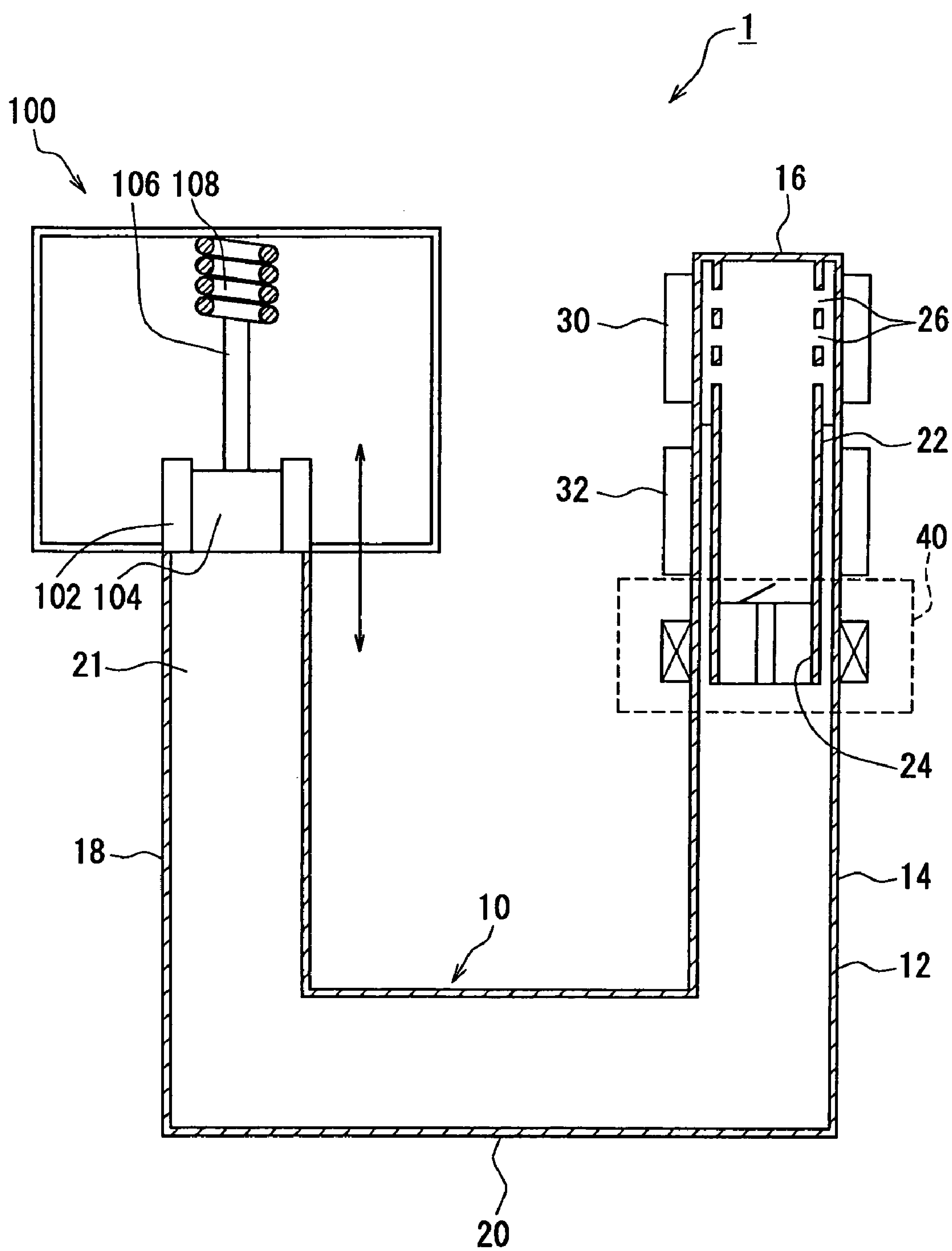


FIG. 2A

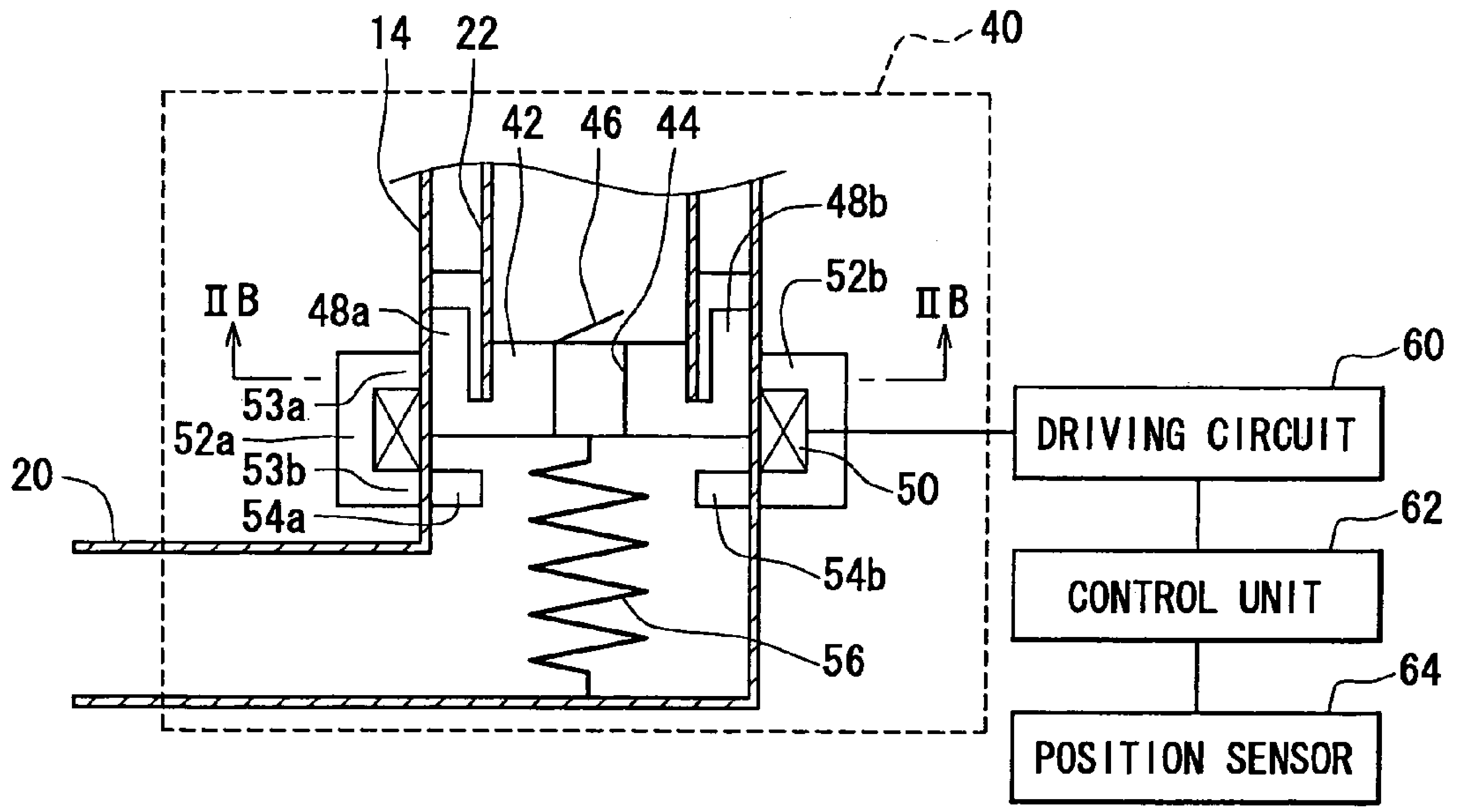

14
22
40
42
46
44
48b
52b
IIB
48a
IIB
60
53a
DRIVING CIRCUIT
52a
53b
50
20
54a
62
54b
CONTROL UNIT
56
64
POSITION SENSOR

FIG. 2B

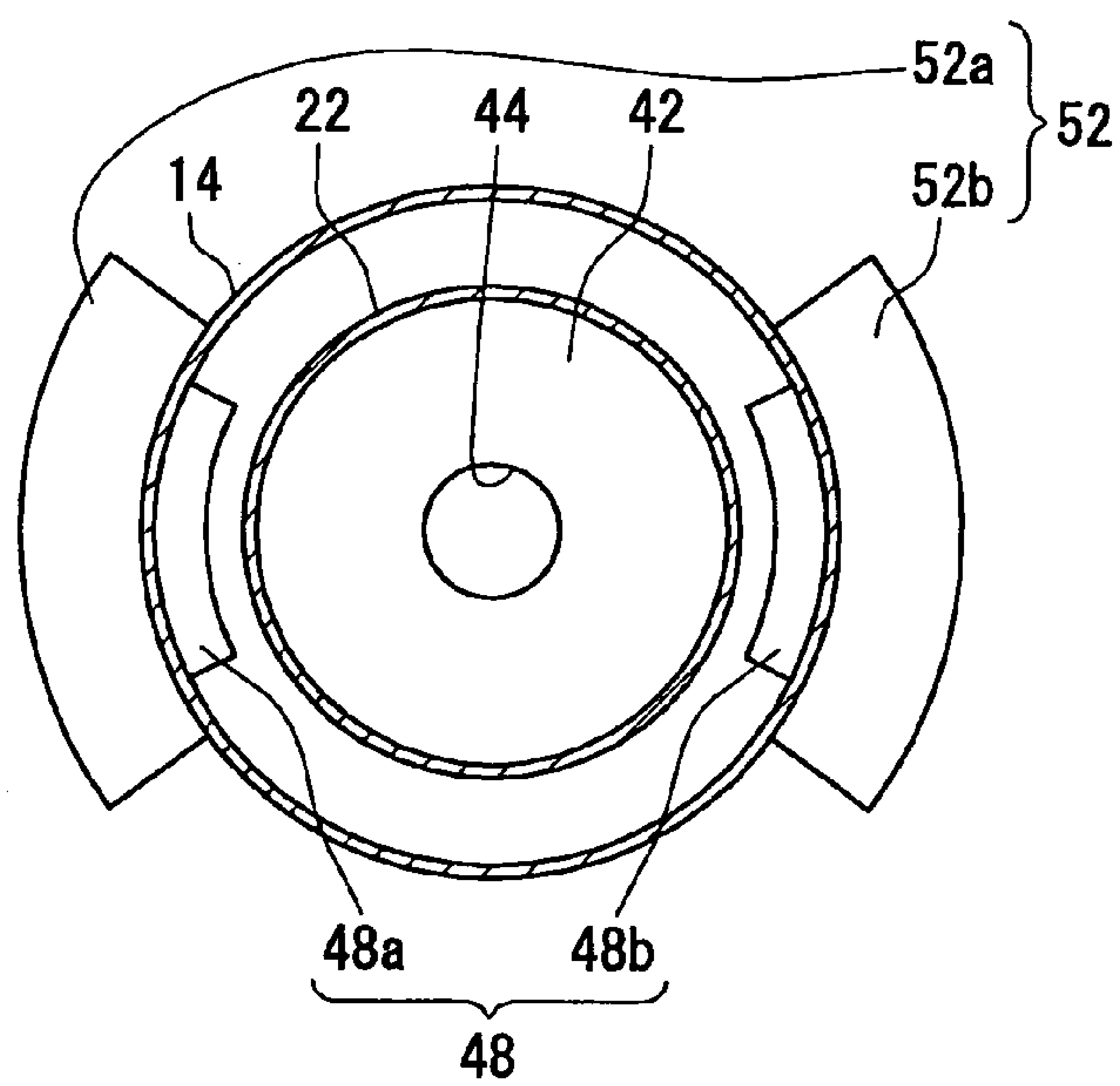

52a
52
22
44
42
14
52b
48a
48b
48

FIG. 3A

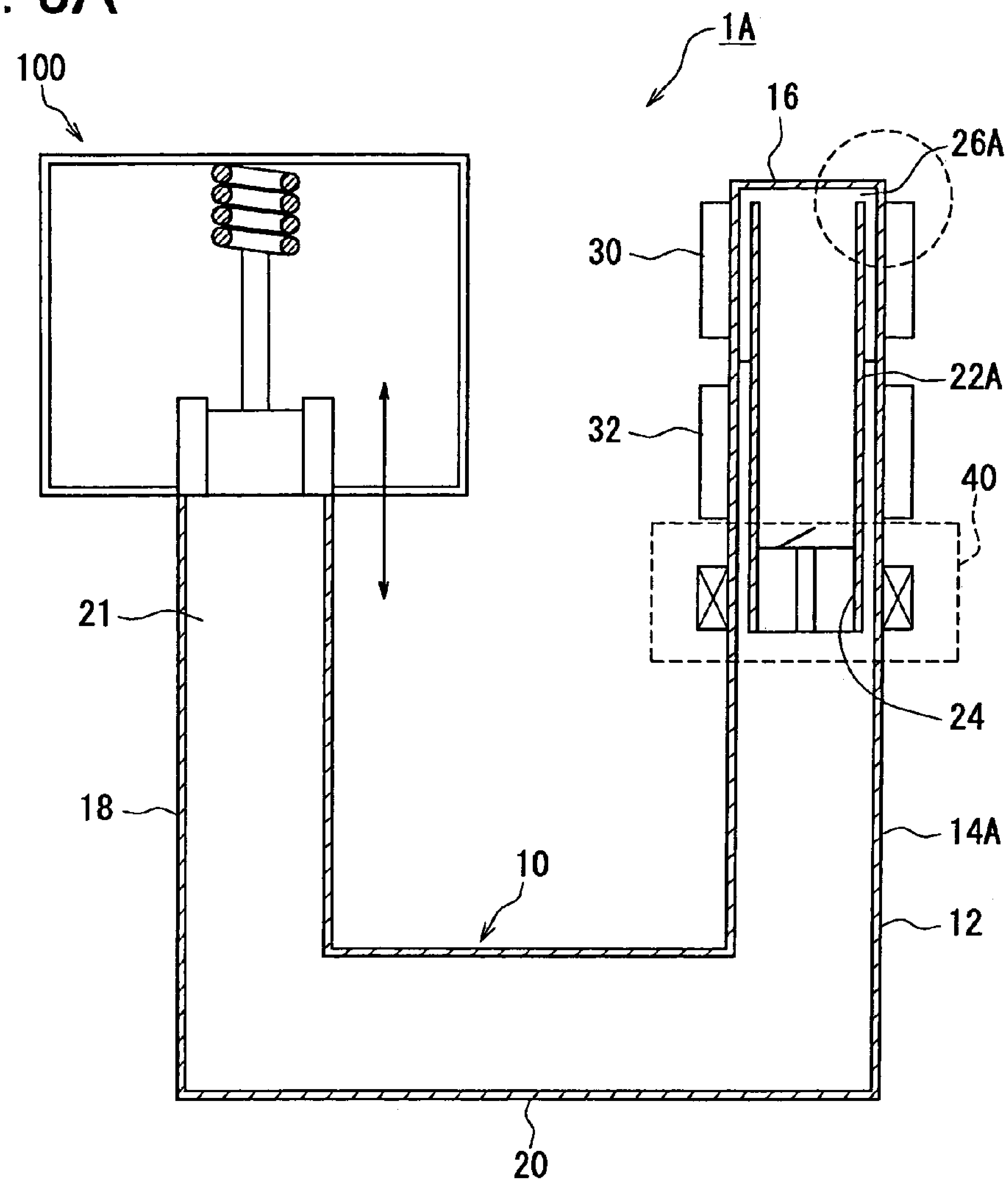

1A
100
16
26A
30
22A
32
40
21
24
18
14A
10
12
20

FIG. 3B

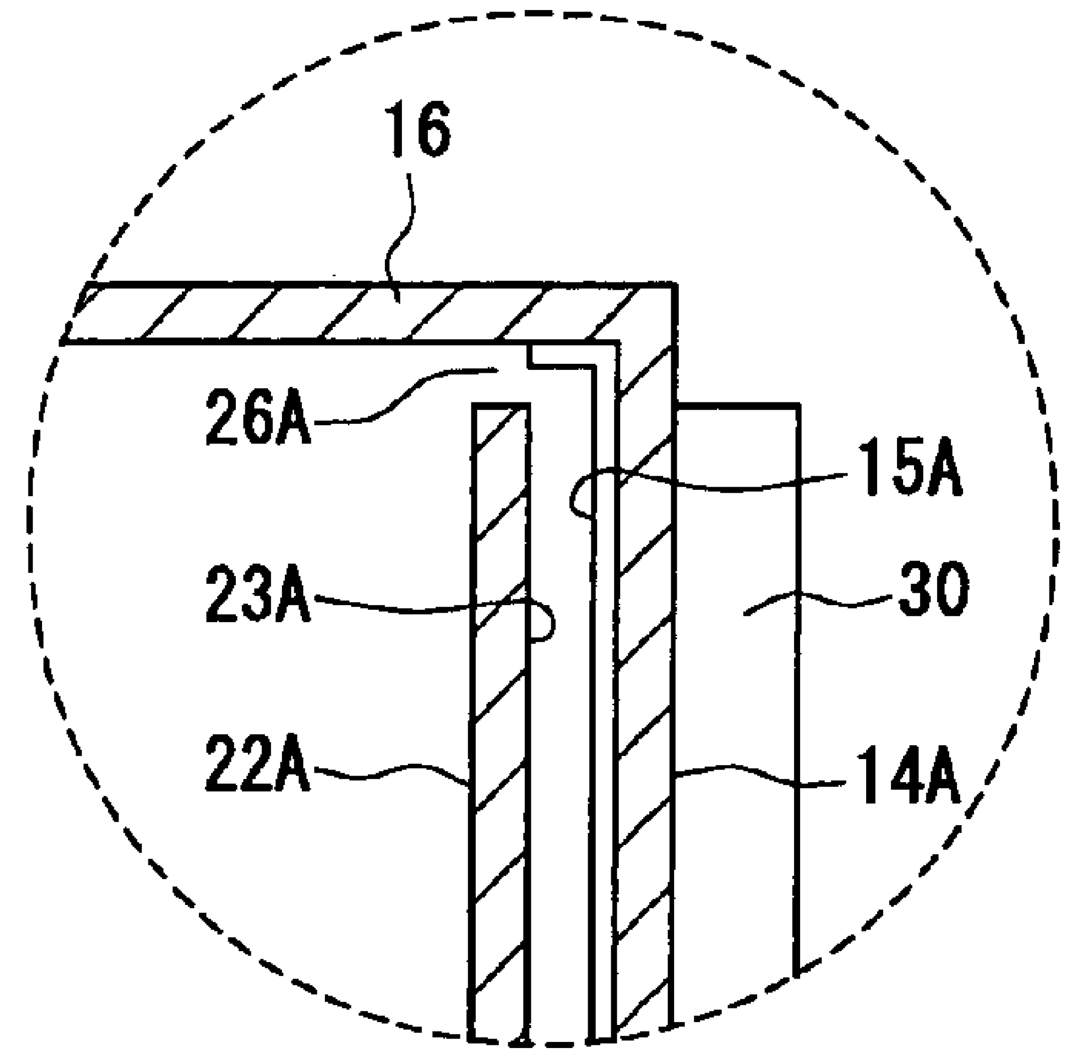

16
26A
15A
23A
30
22A
14A

FIG. 4

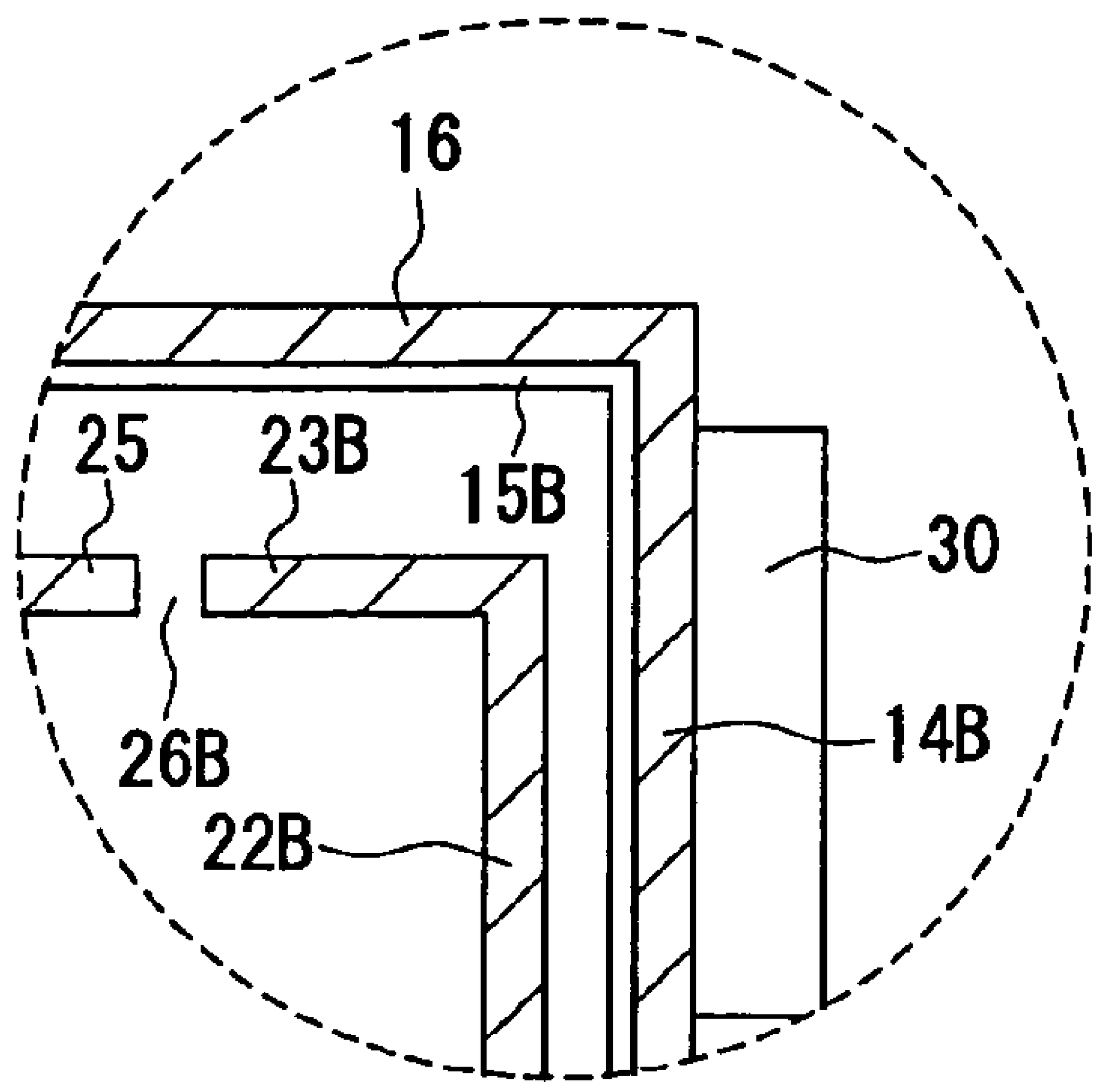


FIG. 5

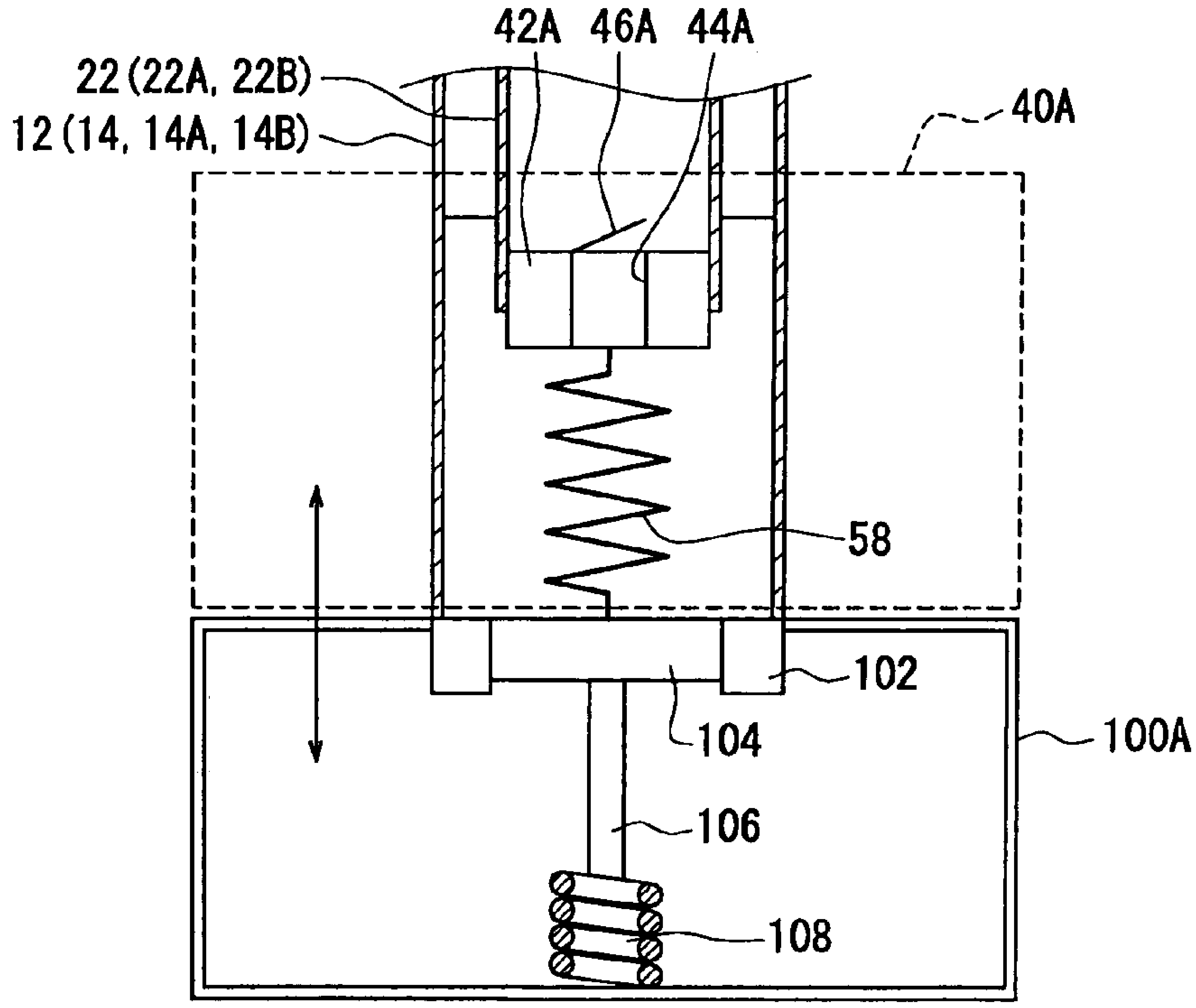


FIG. 6

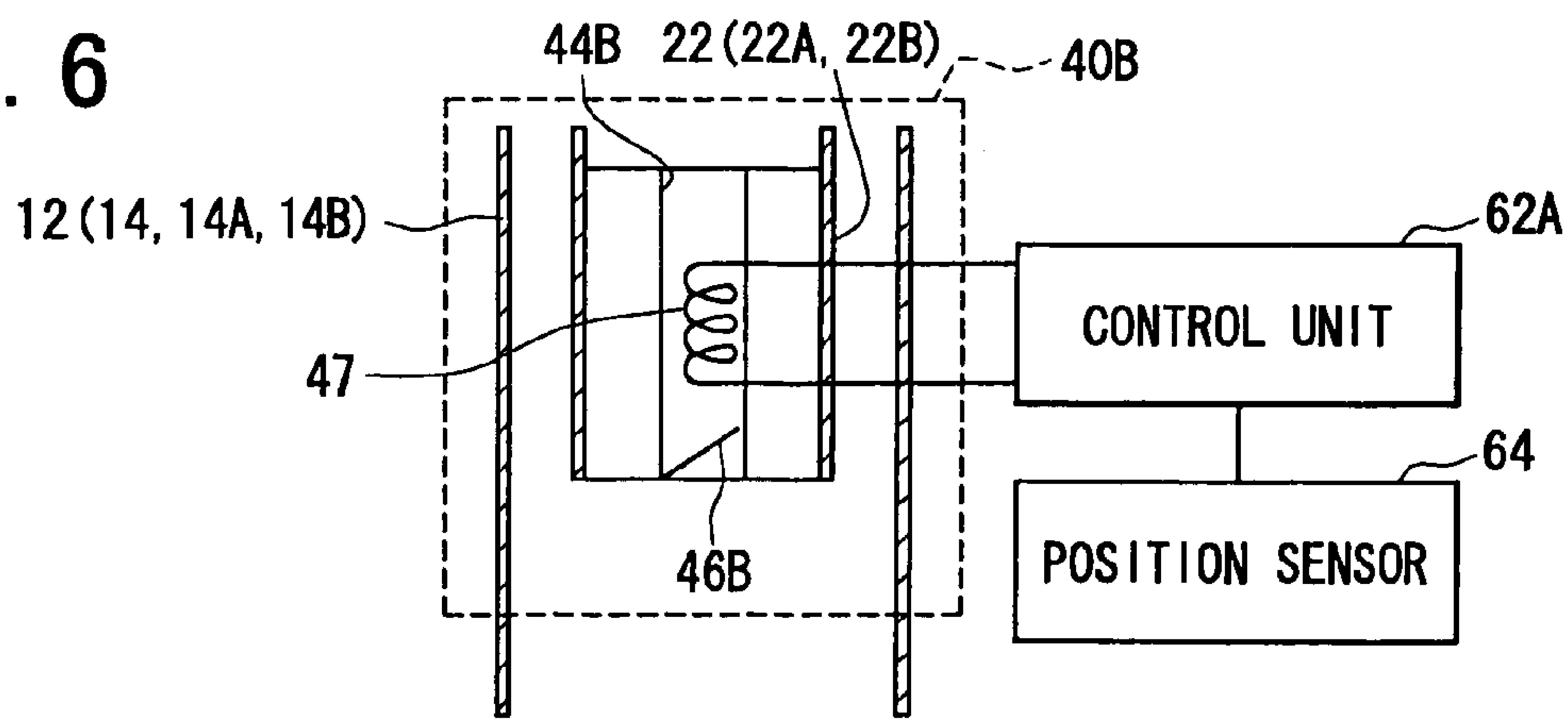
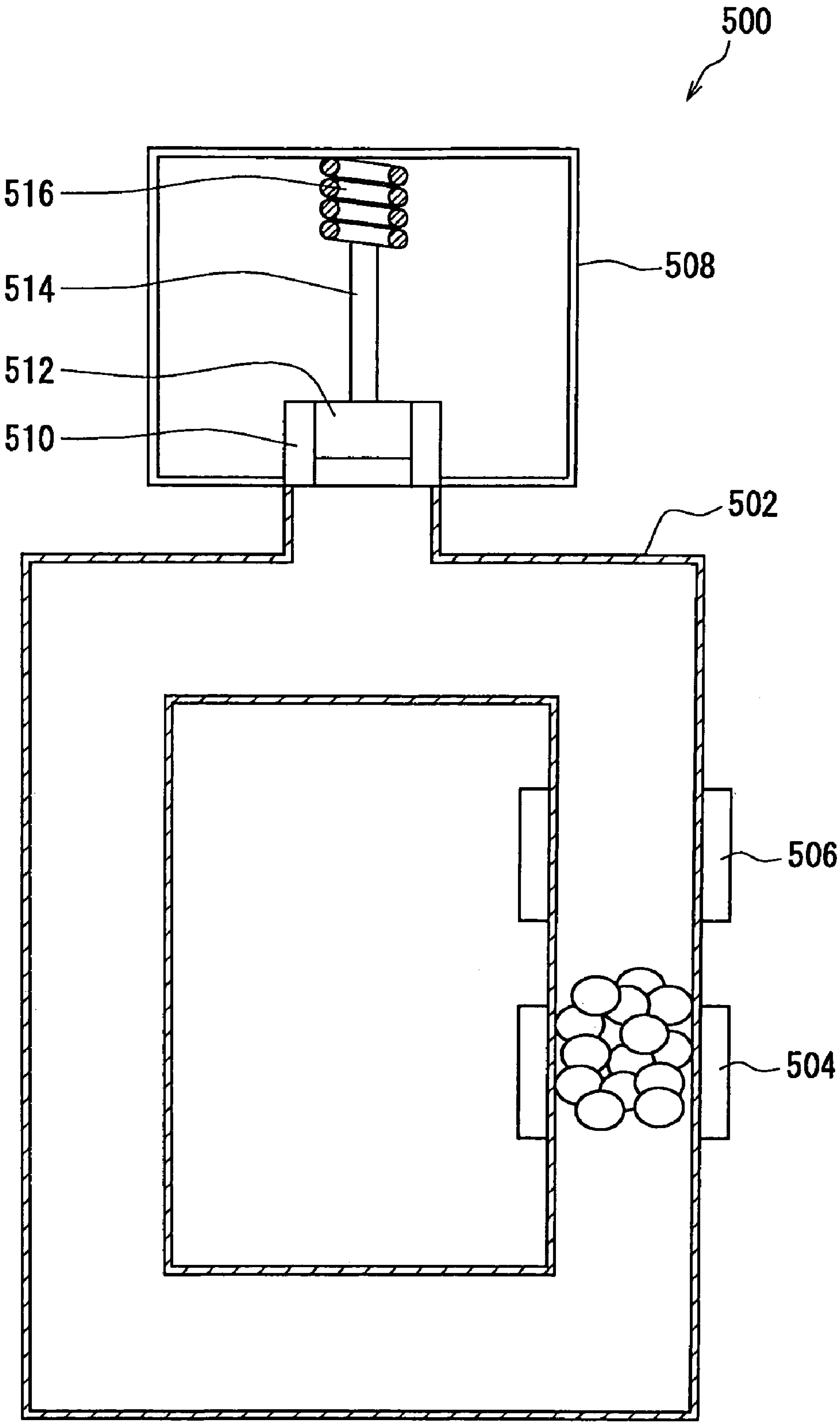


FIG. 7 RELATED ART



STEAM ENGINE

CROSS REFERENCE TO RELATED APPLICATION

This application is based on Japanese Patent Application No. 2004-063014 filed on Mar. 5, 2004, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a steam engine having a fluid container, in which working fluid is filled and the working fluid is vibrated in the fluid container in a self-excited vibrating manner as a result of a repeated operation of vaporization and liquefaction of the working fluid by heating and cooling the working fluid.

BACKGROUND OF THE INVENTION

An apparatus for a steam engine is known in the art, for example as disclosed in Japanese Patent Publication No. H7-180649, in which energy is obtained by repeating vaporization and liquefaction of fluid.

In the above apparatus, volatile fluid is filled in a heating chamber, wherein the fluid is vaporized by heating the same and vaporized fluid is introduced into a vertically arranged fluid pipe and guided to an upper portion of the fluid pipe. Then, the vaporized fluid is cooled and liquidized in a cooling chamber provided at the upper portion of the fluid pipe. The liquidized fluid returns to the heating chamber through the fluid pipe. A magnetic member is provided the fluid pipe to cause a movement thereof. An electric power is generated by producing electromotive force at a coil provided at an outside of the fluid pipe.

The applicant of the present invention has proposed a steam engine, as disclosed in Japanese Patent Publication No. 2002-245165 (which corresponds to U.S. patent Publication No. 2004/0060294 A1), in which working fluid in a fluid container is vibrated in a self-excited vibrating manner as a result of a repeated operation of vaporization and liquefaction of the working fluid by heating and cooling the working fluid. And a driving force is obtained from the fluid vibration and finally an electric power is generated by such driving force.

The above steam engine **500** is shown in FIG. **7**, which comprises a fluid container **502** having a circular fluid passage, a heating device **504** for heating working fluid in the fluid container **502**, a cooling device **506** arranged above the heating device **504** and cooling steam vaporized at the heating device **504**, and an output device **508**. The output device **508** comprises a cylinder **510**, a piston **512** silidably moving back and forth in the cylinder **510**, a moving member **514** connected at its one end to the piston **512**, and a spring **516** connected to the other end of the moving member **514**. The piston **512** is moved in the cylinder **510** in a reciprocating manner in accordance with pressure from the working fluid.

In the above steam engine **500**, volumetric expansion of the working fluid occurs in the fluid container **502**, when the working fluid is heated and vaporized by the heating device **504**. The vaporized steam heated at the heating device **504** moves upwardly toward the cooling device **506**, at which the steam is cooled and liquidized. Volumetric contraction of the working fluid in the fluid container **502** occurs by the liquefaction of the working fluid. The piston **512** and the moving member **514** of the output device **508** are reciprocated by change of liquid surface (self-excited vibration) as the pressure change due to the volumetric expansion and contraction of the working fluid in the fluid container **502**.

Accordingly, electromotive force is generated and thereby electric power can be generated by the reciprocal movement of the piston **512** and the moving member **514**, when a permanent magnet is fixed to the moving member **514** and a coil is provided at a position opposing to the permanent magnet.

It is, however, disadvantageous in the above steam engine **500**, in that thermal efficiency is not sufficiently high.

Namely, when the vaporized steam produced at the heating device **504** moves upwardly, liquid-phase working fluid directly below the steam also moves upwardly and passes through the heating device **504**, so that such working fluid may be heated by the heating device **504** to a temperature at which the fluid can not be vaporized.

In the case that the working fluid passing through the heating device **504** is heated but not vaporized, thermal energy supplied to the working fluid passing through the heating device **504** as the liquid-phase working fluid does not contribute to the volumetric expansion of the working fluid in the fluid container **502**, and thereby such energy can not be used for the reciprocal movement of the piston **512** and the moving member **514**.

As above, a part of the thermal energy is unnecessarily wasted in the above steam engine **500**, the thermal efficiency is decreased corresponding to such wasted thermal energy.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a steam engine, in which working fluid in a fluid container is vibrated in a self-excited vibrating manner as a result of a repeated operation of vaporization and liquefaction of the working fluid by heating and cooling the working fluid, and in which thermal efficiency is improved.

According to a feature of the present invention, a heating device and a cooling device are provided at a fluid container in which working fluid is filled at a predetermined pressure. The fluid container has a vertically extending outer pipe having an upper closed end, and an inner pipe provided in the outer pipe and having a fluid inlet port through which the inside of the inner pipe is operatively communicated with the outside of the inner pipe. The inner pipe has a pressure control device at its lower end, and a fluid injection port at its upper end for injecting the working fluid in the inner pipe into a space defined between the inner pipe and the outer pipe, when the pressure in the inner pipe is increased by the pressure control device.

According to the above feature of the present invention, the working fluid injected from the inner pipe into the space between the inner and outer pipes is heated and vaporized by the heating device, so that volumetric expansion of the working fluid takes place to increase fluid pressure in the fluid container. The vaporized steam is then cooled and liquidized by the cooling device and thereby the volumetric contraction takes place, so that the fluid pressure is decreased. By repeating the above volumetric expansion and contraction of the working fluid by the heating and cooling devices, the pressure change is given to the working fluid in the fluid container.

The vaporization of the working fluid is performed in the closed circular space defined by the outer and inner pipes, and the closed circular space is formed at a vertically higher position close to the upper end of the outer pipe. And therefore, the steam vaporized by the heating device is prevented from moving upwardly away from the heating device.

Furthermore, the liquid-phase working fluid directly below the steam is prevented from being heated but not vaporized by the heating device and upwardly passing through the heating device. As a result, heat efficiency of the steam engine is improved

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1** is a schematic view showing a steam engine according to a first embodiment of the present invention;

FIG. **2**A is a schematic cross sectional view of a pressure control device of the first embodiment;

FIG. **2**B is a schematic cross sectional view taken along a line IIB—IIB of FIG. **2**A;

FIG. **3**A is a schematic view showing a steam engine according to a second embodiment;

FIG. **3**B is an enlarged cross sectional view showing a portion circled in FIG. **3**A;

FIG. **4** is an enlarged cross sectional view showing the portion circled in FIG. **3**A according to a modification of the second embodiment of the present invention;

FIG. **5** is a schematic cross sectional view showing a pressure control device according to a third embodiment of the present invention;

FIG. **6** is an enlarged partial view schematically showing a pressure control device according to a fourth embodiment of the present invention; and

FIG. **7** is a schematic view showing a steam engine of a related art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(First Embodiment)

A first embodiment of the present invention will now be explained with reference to the drawings.

As shown in FIG. **1**, a steam engine **1** comprises a fluid container **10** in which working fluid, such as water, is filled with a predetermined pressure, a heating device **30**, a cooling device **32**, a pressure control device **40** for increasing or decreasing fluid pressure, and an output device **100** for generating energy as a driving force.

The fluid container **10** comprises an outer pipe **12** and an inner pipe **22**, wherein the outer pipe **12** is formed into a U-shaped pipe having a bottom pipe portion **20** and a pair of (first and second) vertically extending straight pipe portions **14** and **18** extending from both ends of the bottom pipe portion **20**.

The first straight pipe portion **14** has an upper closed end **16** at its upper end, and the inner pipe **22** vertically extending is provided in the first straight pipe portion **14**, wherein an upper end of the inner pipe **22** is fixed to an inner surface of the closed end **16**, while a lower end of the inner pipe **22** is opened to the inside of the outer pipe **12** to form an opening portion **24**. Multiple fluid injection ports **26** are formed at a side wall portion of the inner pipe **22** adjacent to the upper closed end **16** for communicating the inside and outside spaces of the inner pipe **22**.

The heating device **30** is composed of, for example, a heat exchanger, for partly heating and vaporizing the working fluid in the fluid container **10**. The cooling device **32** is likewise composed of, for example, a heat exchanger for cooling and liquidizing the steam vaporized by the heating device **30**. The heating device **30** is provided at an outer periphery of the first straight pipe portion **14** adjacent to the upper closed end **16**, which is also close to the multiple fluid injection ports **26** formed at the inner pipe **22**. The cooling device **32** is also provided at the outer periphery of the first straight pipe portion **14** at a vertically lower position than the heating device **30**. In this embodiment, the vertical position for the cooling device **32** is vertically higher than a position of a lower end of the inner pipe **22** (the opening portion **24**).

A part of the first pipe portion **14**, at which the heating device **30** and the cooling device **32** are provided, is made of such a metal, copper, aluminum and the like, as having high heat conductivity, to effectively perform a heating operation by the heating device **30** and a cooling operation by the cooling device **32**. The other part of the outer pipe **12** is preferably made of heat insulating material. Furthermore, the inner pipe **22** is made of the heat insulating material to suppress heat exchange between the working fluid in the inner pipe **22** and the heating device **30** and the cooling device **32**.

The pressure control device **40** is provided at the first straight pipe portion **14** for generating a pressure change in the working fluid held in the inner pipe **22**. Although, the detail structure and operation of the pressure control device **40** is explained later, the working fluid held in the inner pipe **22** is injected through the multiple fluid injection ports **26** into a circular space defined by the inner pipe **22** and the first pipe portion **14**, when the pressure of the working fluid in the inner pipe **22** is increased to a predetermined value by the pressure control device **40**.

The output device **100** is provided at an upper end **21** of the second pipe portion **18** and generates the electric power in accordance with change of the liquid level (the self-excited level change) appearing at the upper end **21**.

The output device **100** comprises a cylinder **102** connected to the upper end **21** of the second straight pipe portion **18**, a piston **104** silidably moving back and forth in the cylinder **102**, a moving member **106** connected at its one end to the piston **104**, and a spring **108** connected to the other end of the moving member **106**. A permanent magnet (not shown) is fixed to the moving member **106**, and a coil (not shown) is provided at a position opposing to the permanent magnet. The piston **104** and the moving member **106** are reciprocated (moved upwardly and downwardly) in accordance with pressure change of the working fluid in the fluid container **10** (the change of the liquid level at the upper end **21** of the pipe portion **18**). The electromotive force and thereby the electric power is generated at the coil of the output device **100** in accordance the reciprocal movement of the moving member **106**.

The pressure control device **40** is explained with reference to FIGS. **2**A and **2**B.

The pressure control device **40** comprises a moving element **42**, an energizing coil **50**, a stator **52**, inside magnetic elements **54***a*, **54***b* and a spring **56**. The moving element **42** is movably arranged in the inner pipe **22**, and it generates a pressure change to the working fluid in the inner pipe **22** by its reciprocal movement in upward and downward directions.

A fluid inlet port **44** is formed at a center of the moving element **42** for communicating the spaces above and below the moving element **42** with each other.

A one way valve **46** is provided at the fluid inlet port **44**, so that the fluid inlet port **44** is opened to allow the working fluid to flow into the inside of the inner pipe **22**, when the pressure of the working fluid in the inner pipe **22** is decreased by the downward movement of the moving element **42**, while the fluid inlet port **44** is closed to prevent the working fluid from flowing into the inside space of the inner pipe **22** (namely, to prevent the working fluid from flowing out from the inside of the inner pipe **22**), when the pressure of the working fluid in the inner pipe **22** is increased by the upward movement of the moving element **42**.

A pair of guide members **48** is provided to the moving element **42**, each forward end **48***a,* **48***b* of which is inserted into the circular space defined by an inner peripheral surface of the outer pipe **14** and an outer peripheral surface of the inner pipe **22** when the moving element **42** is upwardly moved to its uppermost position. Each of the forward ends **48***a* and **48***b* is formed into an arc shape to form arc spaces between the forward ends **48***a* and **48***b,* so that the working fluid may flow from the inside of the outer pipe **14** below the moving element **42** to the circular space and vice versa, as shown in FIG. **2**B.

The energizing coil **50** is an electromagnetic solenoid coil of a ring shape provided at an outer peripheral surface of the outer pipe **14** at such a position, at which the energizing coil **50** is opposed to the moving element **42**.

The stator **52** comprises a pair of arc-shaped stator elements **52***a* and **52***b* provided at the outer peripheral surface of the outer pipe **14** at such a position, at which the stator elements **52***a* and **52***b* are respectively opposed to the guide members **48***a* and **48***b,* as shown in FIG. **2**B. Each of the arc-shaped stator elements **52***a* and **52***b* has a U-shaped cross sectional configuration, as shown in FIG. **2**A, wherein the ring-shaped solenoid coil **50** is housed in arc-shaped grooves of the stator elements **52***a* and **52***b*. Each of the arc-shaped stator elements **52***a* and **52***b* further has an upper end **53***a* and a lower end **53***b* facing to the outer peripheral surface of the outer pipe **14**.

The pair of inside magnetic elements **54***a* and **54***b* is fixed to the inner surface of the outer pipe **14** at such a position opposing to the respective lower ends **53***b* of the stator elements **52***a* and **52***b*.

Accordingly, an electromagnetic path is formed by the upper ends **53***a* of the stator element **52***a* and **52***b,* the guide members **48***a* and **48***b,* the inside magnetic elements **54***a* and **54***b,* and the lower ends **53***b* of the stator elements **52***a* and **52***b,* when the electric power is supplied to the solenoid coil **50**.

The spring **56** is connected at its one end with the moving element **42** and at its other end with the inner surface of the outer pipe **14**, for upwardly urging the moving element **42**, so that the moving element **42** is placed at its upper-most position by the spring force of the spring **56**, as shown in FIG. **2**A, when the electric power supply to the solenoid coil **50** is cut off.

The solenoid coil **50** is connected to a control unit **62** (generally comprising a computer) via a driving circuit **60**. A position sensor **64** is provided in the output device **100** to detect positions of the piston **104**, and a detected signal from the position sensor **64** is inputted into the control unit **62**, so that the control unit **62** controls the electric power supply to the solenoid coil **50** in accordance with the detected position of the piston **104**.

When the electric power is supplied to the solenoid coil **50** by the control unit **64**, the magnetic field is generated by the solenoid coil **50**, and the magnetic poles are thereby formed at the upper and lower ends **53***a* and **53***b* of the stator elements **52***a* and **52***b*. As result, the moving element **42** is pulled down toward the inside magnetic elements **54***a* and **54***b* against the spring force of the spring **56**.

In the embodiment, the inner pipe **22** is almost fully filled with the working fluid, when the electric power is supplied to the solenoid coil **50** and thereby the moving element **42** is pulled down to its lowermost position, so that the pressure in the inner pipe **22** is made relatively lower.

Furthermore, in the embodiment, liquid level of the working fluid in the circular space between the inner and the outer pipes **22** and **14** is maintained at such a position vertically lower than the heating device **30**, even when the pressure in the inner pipe **22** is made lower. For example, the liquid level is maintained at a position between the heating device **30** and the cooling device **32**, as shown in FIG. **1**.

An operation of the steam engine **1** according to the first embodiment is explained.

The electric power is supplied to the solenoid coil **50**, the moving element **42** is pulled down to its lowermost position and the pressure in the inner pipe **22** is made lower, as explained above. Then, the electric power supply to the solenoid coil **50** is cut off by the operation of the control unit **62**, so that the moving element **42** moves up by the spring force of the spring **56** toward its uppermost position.

In this operation, the one way valve **46** is closed to prevent the working fluid from flowing into the inside of the inner pipe **22**, and the pressure of the working fluid in the inside of the inner pipe **22** is rapidly increased in accordance with the upward movement of the moving element **42**.

The working fluid in the inside of the inner pipe **22** is injected from the multiple fluid injection ports **26** into the circular space defined by the outer pipe **14** and the inner pipe **22**, when the pressure of the working fluid in the inside of the inner pipe **22** is increased as above.

Since the fluid injection ports **26** are formed in the inner pipe **22** adjacent to the heating device **30**, the working fluid injected from the fluid injection ports **26** are heated and vaporized by the heating device **30**. As a result, the working fluid in the circular space is volumetrically expanded due to the vaporization of the injected working fluid, and thereby the working fluid in the fluid container **10** is volumetrically expanded.

When the volumetric expansion of the working fluid occurs as above, the liquid level of the working fluid in the circular space between the inner pipe **22** and the outer pipe **14** is pulled down and the liquid level at the upper end **21** of the second straight pipe portion **18** is pushed up. The piston **104** and the moving member **106** of the output device **100** are thereby upwardly moved in accordance with the upward movement of the liquid level at the upper end **21**.

A lower part of the steam vaporized by the heating device **30** moves downwardly, even below the heating device **30**, in accordance with the volumetric expansion by the vaporization. The lower part of the steam reaches a vertical position at which the cooling device **32** is provided.

Then, the steam is cooled and liquidized by the cooling device **32**. The working fluid at the cooling device **32** is contracted due to the liquefaction and thereby the working fluid in the fluid container **10** is contracted as a whole.

When the volumetric contraction of the working fluid occurs as above, the liquid level of the working fluid in the circular space between the inner pipe **22** and the outer pipe **14** goes up and the liquid level at the upper end **21** of the second straight pipe portion **18** goes down. The piston **104** and the moving member **106** of the output device **100** are likewise downwardly moved in accordance with the downward movement of the liquid level at the upper end **21**.

The above upward and downward movement (the reciprocal movement) of the piston **104** and the moving member **106** is repeated as the result of repeated changes of the liquid level (the self-excited displacement) at the upper end **21** of the second straight pipe portion **18**, so that the electric power is generated at the output device **100**.

The above operation is further explained in detail. The control unit **62** cuts off the electric power supply to the solenoid coil **50**, when it detects that the moving element **106** starts its downward movement from its top dead point based on the signal from the position sensor **64**. Then, the moving element **42** is upwardly moved to inject the working fluid from the fluid injection ports **26**. The injected fluid is heated and vaporized by the heating device **30** to cause the volumetric expansion of the working fluid. As a result, the driving force for the upward movement is applied to the moving member **106**, when the moving member **106** reaches its bottom dead point.

A time period for cutting off the electric power supply to the solenoid coil **50** is in advance determined by the control unit **62**, so that an optimum amount of the working fluid is injected from the fluid injection ports **26**.

The electric power is supplied to the solenoid coil **50** during a period in which the moving member **106** is upwardly moved from its bottom dead point. During this upward movement of the moving member **106**, the moving element **42** is downwardly moved to decrease the pressure of the working fluid in the inner pipe **22**, so that the fluid inlet port **44** is opened and the working fluid flows into the inside of the inner pipe **22**.

When the part of the steam is cooled and liquidized by the cooling device **32** and thereby the working fluid is contracted, the moving member **106** starts again its downward movement. Then the control unit **62** stops the electric power supply to the solenoid coil **50** based on the signal from the position sensor **64**.

As above, the moving member **106** is repeatedly reciprocated to generate the electric power at the output device **100**.

The steam engine **1** of the above embodiment has the following features and advantages.

(1) The vaporization of the working fluid is performed in the closed circular space defined by the outer and inner pipes **14** and **22**, and the closed circular space is formed at a vertically higher position close to the upper end **16** of the straight pipe portion **14**. And therefore, the steam vaporized by the heating device **30** is prevented from moving upwardly away from the heating device **30**.

Furthermore, the liquid-phase working fluid directly below the steam is prevented from being heated but not vaporized by the heating device **30** and upwardly passing through the heating device **30**. As a result, heat efficiency is improved by such a degree in which the above phenomenon is suppressed.

(2) The inner pipe **22** is made of the heat insulating material, and only the working fluid adjacent to the heating device **30** is heated, so that such working fluid is vaporized to further improve the heat efficiency.

(3) When the moving element **42** is downwardly moved and thereby the pressure in the inside of the inner pipe **22** is made lower, the inside of the inner pipe **22** is fully filled with the liquid-phase working fluid. Therefore, when the moving element **42** is upwardly moved to increase the pressure of the working fluid in the inner pipe **22**, the working fluid is rapidly injected from the fluid ports **26** into the circular space defined by the inner pipe **22** and the outer pipe **14**. The response of the steam engine **1** (the injection of the working fluid due to the upward movement of the moving element **42**) is improved.

(4) The one way valve **46** is provided at the fluid inlet port **44**, so that the fluid inlet port **44** is opened when the moving element **42** is downwardly moved, while it is closed when the moving element **42** is upwardly moved. Accordingly, the working fluid is smoothly supplied into the inner pipe **22**, whereas the pressure of the fluid in the inner pipe **22** can be rapidly increased, in accordance with the downward and upward movement of the moving element **42**.

(5) Furthermore, the liquid level of the working fluid in the circular space between the inner pipe **22** and the outer pipe **14** is kept at the position vertically lower than the heating device **30**, when the moving element **42** is downwardly moved and the pressure in the inner pipe **22** is made lower. Accordingly, there exists only the working fluid at the heating device **30** when the working fluid is injected from the fluid injection ports **26**, and thereby the heat of the heating device **30** is effectively transmitted to the injected working fluid to facilitate the vaporization. As a result, the heat efficiency of the steam engine **1** is further improved due to the rapid vaporization of the working fluid.

(6) The cooling device **32** is provided at a position vertically higher than the lower end of the inner pipe **22**, so that the working fluid (the steam) can be rapidly cooled and condensed to improve its cooling efficiency.

(7) Multiple fluid injection ports **26** are provided at the inner pipe **22**, so that a sufficient amount of the working fluid can be injected through such fluid injection ports **26** during a short period of time. Since the large amount of the working fluid can be vaporized during the short time period, the frequency of the self-excited displacement can be correspondingly increased.

(8) Since the guide members **48***a,* **48***b* made of magnetic material are fixed to the moving element **42**, the moving element **42** can be quickly moved in the downward direction. Furthermore, since the inside magnetic elements **54***a,* **54***b* are provided in the inner surface of the outer pipe **14**, the downward movement of the moving element **42** can be further effectively done.

(9) The spring **56** is provided to upwardly move the moving element **42**, when the electric power supply to the solenoid coil **50** is cut off. And therefore, energy efficiency is improved.

(10) The movement of the moving element **42** is controlled by the control unit **62** based on the detected position signal for the piston **104** (and/or the moving member **106**) provided in the output device **100**, so that the movement of the moving element **42** is synchronized with the movement of the piston **104**, to improve the efficiency of the electric power generation.

The above described first embodiment can be modified in various manners, as below.

The inner pipe **22** can be made of such material having lower heat conductivity than the outer pipe **14**, instead of the heat insulating material.

The moving element **42** can be arranged so that its downward movement is carried out by a spring force, during which the electric power supply is stopped. The upward movement of the moving element **42** is then carried out by the electromagnetic force.

A permanent magnet can be used as, or additionally fixed to, the guide members **48***a,* **48***b*. In this modification, the moving element **22** is moved up and down by attracting or bouncing forces between the guide members **48** and the magnetic poles formed at the stator **52**. As a result, the spring **56** can be eliminated. The inside magnetic elements **54***a*, **54***b* are used as stoppers for limiting the downward movement of the moving element **42**.

(Second Embodiment)

A second embodiment of the present invention is explained with reference to FIGS. **3**A and **3**B.

The second embodiment differs from the first embodiment in the following points.

Multiple fluid injection ports **26**A are provided at an upper end of an inner pipe **22**A. An inside surface of an outer pipe **14**A adjacent to the heating device **30** is formed as a hydrophilic surface **15**A, as shown in FIG. **3**B. And an outside surface of the inner pipe **22**A adjacent to the heating device **30** is formed as a water repellent surface **23**A.

The above hydrophilic surface and water-repellent surface can be formed by the following methods (but not limited to those methods). The upper end portions of the outer pipe **14**A and the inner pipe **22**A are manufactured respectively by those materials having the hydrophilic characteristic and the water-repellent characteristic. Coating material respectively having those characteristics can be coated on the surfaces of the outer pipe **14**A and the inner pipe **22**A. Or, the surface-roughness of the respective surfaces is adjusted.

The steam engine **1** of the above second embodiment has the following features and advantages, in addition to those of the first embodiment.

(1) The working fluid injected or flowing out from the multiple fluid injection ports **26**A downwardly flows on and along the inside surface **15**A of the outer pipe **14**A. The liquid-phase working fluid can be held on the inside surface **15**A for a longer time period, and thereby heated and surely vaporized. Furthermore, the liquid-phase working fluid is widely spread over the inside surface **15**A adjacent to the heating device **30** due to capillary forces, because the inside surface **15**A is formed as the hydrophilic surface.

(2) The working fluid injected or flowing out from the multiple fluid injection ports **26**A and adhered to the outside surface **23**A quickly flows downwardly along the outside surface **23**A, because it is formed as the water-repellent surface. Accordingly, the amount of the working fluid which would be heated but not be vaporized by the heating device **30** can be reduced, to further improve the heat efficiency of the steam engine **1**.

The inner pipe **22**A and the outer pipe **14**A can be modified to an inner pipe **22**B and an outer pipe **14**B, as shown in FIG. **4**, wherein the inner pipe **22**B is provided with a top end portion **23**B for closing an upper top portion **25** of the inner pipe **14**B, and a fluid injection port **26**B (multiple fluid ports) is formed at the top end portion **23**B. In this modification, the inner pipe **22**B is fixed to the outer pipe **14**B by any suitable means (not shown).

An inside surface of the upper closed end **16** and side wall of the outer pipe **14**B adjacent to the heating device **30** is formed as the hydrophilic surface **15**B, while an outside surface of the upper top portion **25** and a side wall of the inner pipe **22**B adjacent to the heating device **30** is formed as a water-repellent surface.

In such modification, the working fluid flowing out of the fluid injection ports **26**B is formed into liquid drops of spherical configuration due to the water-repellent characteristic at the outside surface of the upper top portion **25**. The liquid drops will grow up to larger liquid drops and come in contact with the inside surface **15**B (the hydrophilic surface) of the outer pipe **14**B.

The liquid-phase working fluid becoming in contact with the inner surface **15**B is spread over to the inside surface of the side wall of the outer pipe **14**B, due to the capillary force.

As above, the working fluid from the fluid injection ports **26**B can be effectively heated and vaporized by the heating device **30**. And the working fluid is further prevented from staying for a longer time period on the outside surface of the inner pipe **22**B, because of the water-repellent surface.

(Third Embodiment)

A third embodiment of the present invention is explained with reference to FIG. **5**, showing a modified pressure control device **40**A. Although the outer pipe **12** is indicated as a straight pipe in FIG. **5**, it can be a U-shaped pipe as in the same manner to the first embodiment.

The third embodiment differs from the first or second embodiment in the structure of the pressure control device **40**A.

The pressure control device **40**A comprises a moving element **42**A and a spring **58** connected at its one end to the moving element **42**A and at its other end to the moving member **106** of the output device **100**A via the piston **104**. The pressure change in the inside of the inner pipe **22** (**22**A, **22**B) is generated by the reciprocal movement of the moving element **42**A in the inner pipe **22**.

A fluid inlet port **44**A and a one way valve **46**A, which are the same or similar to the first embodiment, are also provided to the moving element **42**A. The guide members **48***a*, **48***b* of the first embodiment are eliminated in this embodiment. Furthermore, such components corresponding to the solenoid coil **50**, the stator **52**, the inside magnetic elements **54***a*, **54***b*, and the spring **56** in the first embodiments, are not provided in the pressure control device **40**A.

Even in the above simplified embodiment, the movement of the moving element **42**A can be synchronized with the movement of the moving member **106** (the piston **104**) depending on spring characteristic, such as a spring constant or the like, to generate the electric power in a preferred mode.

A start-up assisting means can be added to the above third embodiment, to smoothly start up the operation of the steam engine **1**. For example, an electromagnetic coil is provided in the output device **100**A, and the electric power is supplied to the coil only during a stat-up period of the steam engine. In this modification, the moving member **106** and the piston **104** are vertically moved by the electromagnetic force of the coil at the start-up period, and thereafter the steam engine continues its operation by itself.

(Fourth Embodiment)

A fourth embodiment of the present invention is explained with reference to FIG. **6**, showing a modified pressure control device **40**B.

The fourth embodiment differs from the first or second embodiment in the structure of the pressure control device **40**B.

The pressure control device **40**B comprises a fixed element fixed to the lower end of inner pipe **22** (or **22**A, **22**B), a one way valve **46**B provided at a lower end of a fluid inlet port **44**B, and a heating coil **47** provided in the fluid inlet port **44**B and controlled by a control unit **62**A. According to this embodiment, the working fluid is heated and vaporized by the heating coil **47** in the fluid inlet port **47**, to increase the pressure in the inner pipe **22**. The steam (the vaporized working fluid by the heating coil **47**) is cooled and condensed by the liquid-phase cold working fluid in the inner pipe **22**, when the steam goes up in the inner pipe **22**.

The position signal for the piston **104** is inputted into the control unit **62**A from the position sensor **64**, and the control unit **62**A controls the heating operation by the heating coil **47** in accordance with the detected position signal.

The control operation is explained below more in detail. The control unit **62**A starts the heating operation by the heating coil **47**, when it detects from the position signal of the position sensor **64** that the moving member **106** (as well as the piston **104**) starts its downward movement from its top dead point. The pressure in the inner pipe **22** is increased and the lower end of the fluid inlet port **44**B is closed by the one way valve **46**B. The working fluid in the inner pipe **22** is injected from the fluid injection ports **26** (or **26**A, **26**B) into the circular space, as in the same manner to the first embodiment, at such a timing at which the moving member **106** is about to reach its bottom dead point. Then the injected working fluid is heated and vaporized by the heating device **30** to generate the volumetric expansion of the working fluid, and to increase the pressure of the fluid in the fluid container **10**.

A time period for heating the fluid in the fluid inlet port **44**B by the heating coil **47** is memorized in advance and controlled by the control unit **62**A, so that an amount of the working fluid to be injected from the fluid injection ports **26** is controlled at an optimum amount. The heating operation by the heating coil **47** is stopped by the operation of the control unit **62**A during a period in which the moving member **106** is upwardly moving from its bottom dead point. In this period, the pressure in the inner pipe **22** becomes relatively lower, so that the one way valve **46**B is opened and the working fluid flows into the inside of the inner pipe **22**.

When the vaporized steam by the heating device **30** is cooled and condensed by the cooling device **32**, the volumetric contraction starts and thereby the moving member **106** starts again its downward movement. The heating coil **47** is again heated by the control unit **62**A.

According to the fourth embodiment, the electric power is generated at the output device **100** by repeating the above operation (the reciprocal movement of the moving member **106** and the piston **104**).

According to the above fourth embodiment, the pressure change in the inner pipe **22** can be carried out by the heating coil **47**. Since the moving element **42** (or **42**A) is not necessary in this embodiment, the steam engine **1** can be made simpler than the first or second embodiment. The same effect to the first embodiment can be also obtained in the fourth embodiment.

What is claimed is:

1. A steam engine comprising:

a fluid container in which working fluid is filled and the working fluid can move;

a heating device for heating the working fluid in the fluid container and vaporizing the working fluid; and

a cooling device for cooling down and liquidizing the steam vaporized by the heating device,

wherein self-excited movement of the working fluid in the fluid container is generated by a repeated operation of vaporization and liquefaction of the working fluid by the heating device and the cooling device,

wherein the fluid container comprises;

a vertically extending outer pipe having an upper closed end at its upper end, the heating device and the cooling device being provided at an outer peripheral surface of the outer pipe and the heating device being arranged at a vertically higher than the cooling device;

an inner pipe provided in the outer pipe and having a fluid inlet port for operatively communicating the inside of the inner pipe with the outside thereof;

a pressure control device provided at a lower end of the inner pipe for opening and closing the fluid inlet port;

a fluid injection port provided at an upper portion of the inner pipe for injecting the working fluid into a space defined by the outer pipe and the inner pipe, when pressure in the inner pipe is increased.

2. A steam engine according to claim **1**, wherein

multiple fluid injection ports are provided at the upper portion of the inner pipe.

3. A steam engine according to claim **1**, wherein

an upper end of the inner pipe is fixed to an inside surface of the upper closed end of the outer pipe, and

the fluid injection port is formed at a side wall of the inner pipe close to its upper end.

4. A steam engine according to claim **1**, wherein

an inside surface of the outer pipe adjacent to the heating device is formed by hydrophilic surface.

5. A steam engine according to claim **1**, wherein

an outside surface of the inner pipe adjacent to the heating device is formed by a water-repellent surface.

6. A steam engine according to claim **1**, wherein

the inner pipe is made of heat insulating material.

7. A steam engine according to claim **1**, wherein

the inner pipe has a lower heat conductivity than the outer pipe.

8. A steam engine according to claim **1**, wherein

the inner pipe is almost fully filled with liquid-phase working fluid when the pressure in the inner pipe becomes lower.

9. A steam engine according to claim **1**, wherein

a liquid level of the working fluid in the space defined by the inner pipe and the outer pipe is kept at a position vertically lower than the heating device, when the pressure in the inner pipe is controlled at a lower pressure by the pressure control device and no working fluid is injected from the fluid injection port.

10. A steam engine according to claim **1**, wherein

the cooling device is provided at the outer peripheral surface of the outer pipe at a position vertically higher than a lower end of the inner pipe.

11. A steam engine according to claim **1**, wherein

the pressure control device comprises;

a moving element for applying a pressure change to the working fluid in the inner pipe by its reciprocal movement; and

a driving means for driving the moving element so that the moving element reciprocates in the inner pipe.

12. A steam engine according to claim **11**, wherein

the moving element has a guide member made of magnetic material; and

the driving means drives the moving element by electromagnetic force.

13. A steam engine according to claim **12**, wherein

the driving means comprises;

a ring shaped electromagnetic coil provided at the outer peripheral surface of the outer pipe, to generate the electromagnetic force and drive the moving element by the electromagnetic force.

14. A steam engine according to claim **13**, wherein

the moving element has the guide member made of magnetic material, and the guide member is inserted into the space defined by the outer pipe and the inner pipe.

15. A steam engine according to claim **14**, wherein the driving means comprises;

a stator provided at an outer periphery of the electromagnetic coil and having magnetic pole portions facing to the outer peripheral surface of the outer pipe, the magnetic poles being formed at the magnetic pole portions when electric power is supplied to the electromagnetic coil.

16. A steam engine according to claim **14**, wherein the guide member has a permanent magnet.

17. A steam engine according to claim **11**, further comprising:

a spring for urging the moving element in a direction to hold the moving element at a predetermined position.

18. A steam engine according to claim **1**, wherein the pressure control device comprises a heating means for heating the working fluid in the inner pipe to increase the pressure in the inner pipe and thereby to inject the working fluid from the fluid injection port into the space defined by the outer pipe and the inner pipe.

19. A steam engine according to claim **1**, further comprising:

an output device for generating energy in accordance with the self-excited displacement of the working fluid.

20. A steam engine according to claim **19**, wherein the output device comprises a moving member, which is reciprocated in accordance with the self-excited displacement of the working fluid for generating energy.

21. A steam engine according to claim **20**, further comprising:

a position sensor for detecting a position of the moving member; and

a control unit for controlling an operation of the pressure control device in accordance with detected position of the moving member from the position sensor.

22. A steam engine according to claim **1**, further comprising:

an output device for generating energy in accordance with the self-excited displacement of the working fluid, the output device comprising a moving member, which is reciprocated in accordance with the self-excited displacement of the working fluid,

wherein the pressure control device comprises a moving element for applying a pressure change to the working fluid in the inner pipe by its reciprocal movement; and

a spring connected between the moving member and the moving element.

23. A steam engine according to claim **1**, further comprising:

a one way valve for opening the fluid inlet port when the pressure in the inner pipe is made lower by the pressure control device, so that the working fluid flows into the inner pipe,

the one way valve closing the fluid inlet port when the pressure in the inner pipe is made higher by the pressure control device, so that the working fluid is prevented from flowing into the inner pipe.

24. A steam engine according to claim **1**, wherein the fluid inlet port is formed in the moving element.

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